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Slow Growing Volumetric Subdivision for 3D Volumetric Data

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Slow Growing Volumetric Subdivision for 3D Volumetric Data

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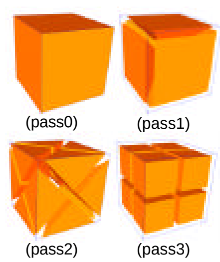
1 Introduction

In recent years subdivision methods have been successfully applied to the multi-resolution representation and compression of surface meshes. Unfortunately their use in the volumetric case has remained impractical because of the use of tensor-product generalizations that induce an excessive growth of the mesh size before sufficient number is preformed. This technical sketch presents a new subdivision technique that refines volumetric (and higher-dimensional) meshes at the same rate of surface meshes. The scheme builds adaptive refinements of a mesh without using special decompositions of the cells connecting different levels of resolution. Lower dimensional "sharp" features are also handled directly in a natural way. The averaging rules allow to reproduce the same smoothness of the two best known previous tensor-product refinement methods [Bajaj et al. 2001;MacCracken and Joy 1996].

2 Slow Growing Volumetric Subdivision

The volumetric subdivision is a generalization of the 4-8 surface subdivision scheme introduced recently in [Velho and Zorin 2001].



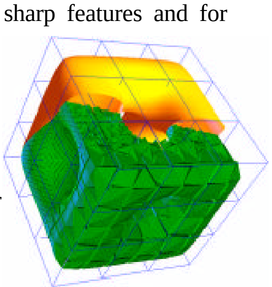
In the 3D case we organize each level of subdivision in four passes, from 0 to 3, where pass 3 of level *l* is coincident with pass *0* of level *l+1* as shown in the figure on the right.

From pass 0 to pass 1. For each cell *c* of the input mesh, a new vertex *p* is inserted at its center. The cell *c* is partitioned in pyramids by connecting *p* to each facet of *c*. Pairs of pyramids with the same base facet *f* are merged together into a cell *F*.

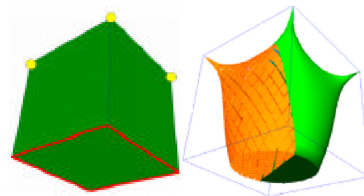
From pass 1 to pass 2. For each facet *f* of the base mesh, a new vertex *q* is inserted at its center. The cell *F* containing *f* is divided in pyramids by connecting *q* to each facet of *F*. Groups of pyramids sharing a base edge *e* are merged into a cell *E*.

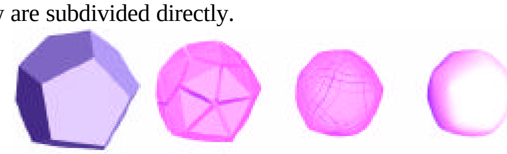
From pass 2 to pass 3. For each edge *e* of the base mesh, a new vertex *r* is inserted at its center. The cell *E* containing *e* is partitioned in pyramids by connecting *r* to each facet of *E*. Groups of pyramids contained in the same base cell *c* and incident to the base vertex *v* are merged into a single cell.

This subdivision in four passes refines gradually a mesh by decomposing first its cells, then its facets and finally its edges. A unified solution for boundary cases, for sharp features and for adaptive refinements, is obtained simply by skipping the merging stages. For example if *f* is a boundary facet there is only one pyramid with base *f* (the cell *F* will have *f* on its boundary). Similarly, if one refines only one of two cells adjacent on *f*, there is only one pyramid with base *f* and the resulting mesh has no hanging node. Therefore, adaptive refinements (see figure on the right) do not require special treatment.

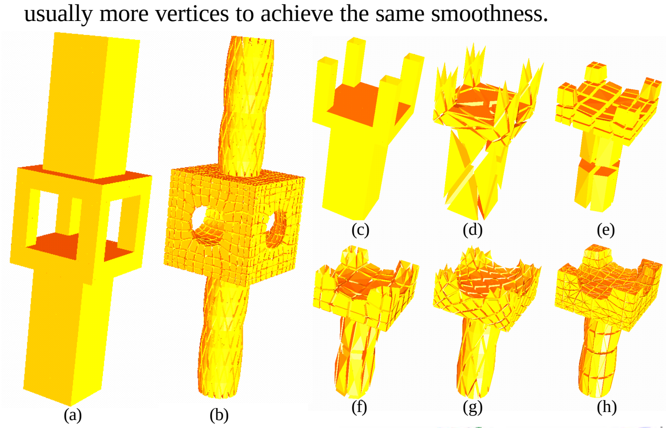


The figure on the right shows the refinement of a cube, where the four top vertices (yellow) are four sharp 0-fieatures, while the bottom edges (red) form a sharp 1-feature. Note that the base mesh is not required to have hexahedral cells. For example, cells like the dodecahedron below are subdivided directly.

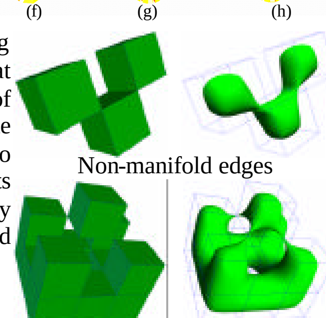




The figure below shows the mesh constructed for a mechanical piece. (a) is the base mesh and (b) the mesh after six refinements. (c-h) are the intermediate steps of the refinement (bottom part of the object). Note that a tensor-product scheme would introduce the same number of vertices in just two refinements, requiring usually more vertices to achieve the same smoothness.



In conclusion the slow growing subdivision is a general tool that allows the practical use of subdivision methods in the volumetric case, extends to higer dimensions and admits base meshes that are virtually unrestricted (e.g. non-mifold features as in the right figure).



Non-manifold edges

Non-manifold vertices

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MacCracken R., AND Joy, K.I. 1996. Free-form deformations with lattices of arbitrary topology. In *Computer Graphics* (SIGGRAPH'96), pages 181--188.

Velho, L., AND Zorin, D. 2001. 4-8 subdivision. *Computer Aided Geometric Design*, volume 18, Issue 5, pp 397-427.

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